WATER RESOURCES REPORT 17

GROUNDWATER RESOURCES OF HOLT COUNTY, MISSOURI

BY

G. E. HEIM. JR.

J. A. MARTIN

and

W. B. HOWE

MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES

Preliminary Report

on the

GROUNDWATER RESOURCES OF HOLT COUNTY, MISSOURI

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STATE OF MISSOURI
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THOMAS R. BEVERIDGE, State Geologist
Rolla, Missouri

PRELIMINARY REPORT ON THE GROUNDWATER RESOURCES

HOLT COUNTY, MISSOURI

COUNTY COVERED BY THIS REPORT

COUNTIES IN WHICH TEST DRILLING HAS BEEN COMPLETED

FIGURE 1

GROUNDWATER RESOURCES OF HOLT COUNTY, MISSOURI

INTRODUCTION

This report has been prepared to aid in the location of groundwater supplies in Holt County. Holt County is one of many counties in western and northern Missouri in which there is either continual or periodic water shortage, and especial difficulty in obtaining adequate amounts of usable ground water. This study is concerned with the location of areas within the county where ground water may be obtained for farm, irrigation, and municipal supplies. Emphasis is placed on ground water from the unconsolidated material above bedrock. Generally, this water is of better quality than either surface or bedrock water. Systematic test-drilling is the most reliable method of determining the areas in which this type of water occurs.

History of Program.-- The study is the continuation of a State sponsored groundwater program begun in 1955. Holt County is the eighteenth county to be studied during this program. Figure 1 shows those counties on which groundwater reports are available from the Missouri Geological Survey, P. O. Box 250, Rolla, Missouri 65401.

The appended bibliography lists the previous work in the area of this report and in adjacent areas. Schweitzer (1892) gives a full discussion and description of the mineral springs and waters in Missouri. Hinds and Greene (1915) and McQueen and Greene (1938) present excellent discussions of the bedrock geology in this and adjacent areas. Their reports contain well logs and discussions on the stratigraphy and structural geology of northwestern Missouri. Greene and Trowbridge (1935) discuss the preglacial drainage pattern of northwestern Missouri,

and their pattern of the major channels is essentially correct. The present program has revealed many tributary channels and modifications of the major pattern. Flint (1957, p. 170) shows the regional drainage patterns during or preceding Pleistocene time. Kay and Apfel (1928) and Frye and Leonard (1952) present discussions of the Pleistocene deposits in adjacent states which may also be applied to this area of Missouri.

The report summarizes the results of the test-drilling program and discusses in detail the water possibilities and the quality of the water from various sources in the county. The information which it presents was derived from: (1) the extensive file of well logs maintained by the Missouri Geological Survey; (2) the study of 22 test holes; and (3) the published and unpublished material related to or concerning water supply in Holt County.

The availability of data from the numerous drill-holes put down in Holt County in the course of oil and gas exploration during past years has resulted in a very significant saving of time and money in the present investigation. In all, only 22 test holes were required to complete coverage comparable to that attained for adjacent counties. The necessary test-drilling was completed during the spring of 1959. Geologists made a detailed log of each hole as it was being drilled. Heim and Martin devoted full time to the test-drilling and associated work during that period, and assembled the material for the present report. Richard Gentile of the Survey staff assisted in some of the logging work. The drilling program and preparation of this report were carried out under the supervision of W. B. Howe.

Location and Size.-- Holt County (Figure 1) is located in the northwestern part of Missouri. It includes 456 square miles and is one of the smallest counties in the state. The population in 1930 was 12,720; in 1940, 12,476, and in 1950, 9,833. This represents a decrease in population of about 2 percent during the 1930-1940 period, and a decrease of over 20 percent during the 1940-1950 period. In population, Holt County ranked ninty-third out of the 114 counties in the state in 1950.

Acknowledgments.-- Mr. W. B. Russell of Layne-Western Company, Kansas City, Missouri, provided information on several wells the company has drilled in Holt County.

Mr. Rex Lane of the Lane Drilling Company, Blanchard, Iowa, was kind enough to supply copies of logs from numerous wells which that company has drilled in the county.

Mr. Frank C. Greene, formerly with the Missouri Geological Survey and now retired, discussed the groundwater problems of the county with the authors on numerous occasions. This assistance is gratefully acknowledged.

The writers also acknowledge the cooperation of Mr. Lloyd Brown, owner of the firm contracting the test-drilling work, and his employees, Mr. J. R. Lamme, driller, and Mr. Frank Benedict, assistant.

The writers also wish to thank the numerous State, County, and City officials for their cooperation. We wish to thank the Holt County residents for their cooperation and interest.

GROUNDWATER RESOURCES

Ground water is defined as that part of rain and snowfall that soaks into the soil and rock of the earth's crust and is stored there. The cracks and crevices and other open spaces in the layers of rock, and the open spaces or voids between grains of sand and gravel in unconsolidated deposits filling river valleys form a natural reservoir for the storage of water. The unconsolidated deposits, and other materials in the earth's crust such as sandstone and limestone, that are porous enough to hold quantities of water are called aquifers.

Ground water in Holt County may be obtained from three sources: (1) alluvium, (2) glacial deposits, and (3) bedrock. Test holes were located in such a manner as to supply the maximum amount of information for the first two of these units. Profiles of the major buried valleys were drawn in order to determine the thickness and extent of any water-bearing material. Survey geologists logged each hole as it was drilled, noting such information as type of material (sand, silt, or clay), size of sand grains, loose drilling zones, and depth to bedrock. Samples were collected at five-foot intervals and were placed on file at the Survey's office in Rolla.

The test holes were drilled with a rotary drilling rig. No casing was used, and samples were collected from the circulating water.

Table 1 summarizes the information from the 22 test holes. This information gives the amount of sand in each test hole and gives in gallons per minute (gpm) the driller's estimated water production which may be available in the vicinity of one or several test holes. Plate 2 shows the number and location of the test holes.

TABLE 1

SUMMARY OF TEST HOLE INFORMATION

Test Hole Number	Location T., R., Sec.	Elevation (feet above mean sea level)	Depth to Bedrock (feet)	Total Amount of sand (feet)	Driller's Production Estimate (gpm)*
1151	62-37-8	970	131	0	0
1152	63-38-36	992	?	8	1-2
1153	62-38-11	1037	?	73	5-10
1154	62-38-14	1052	245	14	1-2
1155	63-38-27	1067	246	10	2-3
1156	62-38-10	1040	240	14	1-2
1157	62-38-4	999	191	14	1
1158	62-38-7	1007	205	38	5
1159	63-39-36	947	127	44	5-10
1160	62-39-11	1020	305	125	10-15
1161	62-39-15	1009	282	19	5-10
1162	62-39-8	1000	287	79	100-200
1163	62-39-20	870	Abandoned at 65 feet, lost circulation		
1164	62-39-17	915	187	99	5-10
1165	61-38-4	1000	153	11	1
1166	61-38-16	1097	394	28	3-5
1167	61-38-20	905	219	104	200-300
1168	60-38-23	1110	149	16	3-5
1169	61-37-29	920	237	24	3-5
1170	61-37-16	930	234	16	1-2
1171	61-37-8	949	115	21	3-5
1172	61-39-2	861	121	77	200-500

*The driller's estimate is based on the character of the sand and gravel, the way in which it drills (loose or tight), and knowledge of what wells in similar materials have produced.

Ground Water from Alluvial Deposits

Alluvium is the unconsolidated material associated with present-day rivers and streams. It consists of clay, silt, sand, pebbles, and boulders. The major alluvial deposits in Holt County are shown on Plate 1.

Missouri River Alluvium.-- The Missouri River floodplain in Holt County encompasses approximately one-fourth of the total area of the county. Two test holes (Nos. 1163 and 1164) were drilled in Missouri River alluvium. Test Hole No. 1163 had to be abandoned at 65 feet after losing circulation. Test Hole No. 1164 was located at the eastern edge of the Missouri River trench. It penetrated 15 feet of alluvium overlying 172 feet of glacial material. The Missouri Geological Survey has information on six producing wells in Missouri River alluvium in Holt County. These wells produce from 70 to 1200 gpm. The maximum known thickness of Missouri River alluvium in Holt County is 133 feet. See Table 3 for an average chemical analysis.

Nodaway River Alluvium.-- No test holes were drilled in Nodaway River alluvium in Holt County. Four test holes were drilled in this material in Nodaway County and the thickness ranged from 27 to 31 feet with estimated production of 0 to 20 gpm. The data from Nodaway County are considered to be representative. The Missouri Geological Survey has information on one producing well in Nodaway River alluvium in Holt County. This well is 45 feet deep and produces 150 gpm. See Table 3 for an average chemical analysis.

Others.-- Alluvial deposits along other smaller rivers and streams in the county may produce small quantities of water, but the thickness

and extent of the water-bearing material is quite variable.

Ground Water from Glacial Deposits

Most of Holt County is covered by clay, silt, sand, gravel, and boulders which were deposited during glacial time. When the glaciers entered Holt County, they deposited this material and covered the then existing topography. Old drainage patterns were buried, and present day drainage developed on this unconsolidated material. In most instances, the buried drainage patterns do not correspond to the present drainage. The channel fillings of sand and gravel are much the same as the alluvial deposits of the present river channels. By means of systematic test-drilling, it is possible to locate and define the pre-existing drainage and to predict areas of potential water production.

Glacial deposits are very complex. Production from shallow sands (depths less than 50 feet) is variable and in dry seasons often ceases. The deeper water-bearing material is more dependable for continued production and constant quantity. Plate 1 shows the thickness of the unconsolidated material in Holt County.

A common misconception is that no water occurs below "blue clay". Of the 21 test holes which encountered glacial material, 19 encountered water-bearing material below the "blue clay".

The buried valley system in Holt County (Plate 2) is not as complex as that in bordering counties. The major valley enters Holt County in the north-central portion of the county, trends southward, loops around the western edge of Mound City, and continues eastward from that point. The deposits that fill this valley form an excellent source of moderate yields of water.

Chemical analyses of water from glacial wells are listed in Table 3.

Ground Water from Bedrock

Limestone, shale and sandstone are present at or near the surface over much of the upland area in the southern half of Holt County. In this area adequate amounts of usable water from wells is extremely difficult to obtain. No test holes were drilled into bedrock formations. Information on file at the Missouri Geological Survey indicates that water from bedrock (limestone, shale, or sandstone) is generally too highly mineralized to be suitable for most uses. The principal constituents which make these waters unfit are the high sodium chloride (salt) and sulfate content. Chemical analyses of water from bedrock wells are listed in Table 3.

The Missouri Geological Survey has records of several wells that were drilled into bedrock in Holt County. The majority of these were drilled for oil exploration, but four were drilled for water. Production from these wells has been very low (1 to 2 gpm or less). Reported production from one bedrock well is 8 gpm; however, it is likely that much of this water actually comes from unconsolidated material above bedrock. The possibilities of obtaining adequate quantities of usable water from the bedrock are very limited.

WATER QUALITY

Water quality is commonly considered from two aspects, bacteriological and chemical. The importance and various limits of these aspects depend upon the use to which the water is to be put. The following discussion deals primarily with water to be used for domestic purposes.

Bacteriological.-- The amount and type of bacteria in water is most important in determining its purity for drinking. Surface water supplies and groundwater supplies that may possibly be contaminated require periodic checking along with constant treatment with purifying agents to insure their safety. Bacteriological analysis reveals the presence of bacteria that may cause typhoid, dysentery, and other such diseases. Any surface supply should be considered contaminated and treated as such. By order of the Division of Health, Jefferson City, Missouri, most groundwater supplies for public use in northwestern Missouri are treated as though contaminated.

In a properly constructed drilled well, there is not much danger of contamination. Proper construction includes adequate provisions for the exclusion of surface water and sterilization of the well upon its completion by the driller. Arrangements for a bacteriological analysis can be made through the district offices of the Division of Health and, in some cases, through the water department of the nearest town having a public water supply.

Chemical.-- The physical and chemical properties of water are very important in determining the type of treatment necessary to make the water usable. Table 2 lists some of the chemical characteristics of acceptable water. Chemical analyses are made by the Division of Health and by the Missouri Geological Survey, Box 250, Rolla, Missouri 65401.

Other information given in a chemical analysis includes remarks about turbidity, odor, hardness, etc. This information can be used to determine the suitability of the water for household use, irrigation, or stock; whether incrustation or corrosion of metals might occur; and

TABLE 2

CHEMICAL CHARACTERISTICS OF WATER FOR DOMESTIC USE

Constituents	Maximum Allowable Amounts in Parts Per Million	Effect of Excess
Chloride	250.0	Salty taste
Fluoride	1.5	Mottling of teeth
Nitrate	45.0	Danger to infants
Iron	0.3	Staining
Sulfate	250.0	Permanent hardness

also to indicate the type of treatment, such as softening or iron removal, that might be beneficial.

In general, the water from alluvial and glacial deposits is hard and contains an excess of iron, and in many cases may require treatment. Bedrock water is more variable, but it is generally too high in chloride and sulfate to be usable.

CITY WATER SUPPLIES

The production given for cities having a municipal supply is based on the capacity of the existing water treatment plants and does not indicate the maximum potential yield of the aquifer.

Bigelow.-- No municipal water supply. Most likely area for future development, Missouri River alluvium.

Corning.-- No municipal water supply. Most likely area for future development, Missouri River alluvium.

Craig.-- Municipal water supply. City has one well located in Missouri River alluvium. The well is 88 feet deep and pumps 70 gpm. Water treatment consists of aeration, chlorination, and addition of soda ash.

Forest City.-- Municipal water supply. Purchase water from system owned by the city of Oregon.

Fortescue.-- No municipal water supply. Most likely area for future development, Missouri River alluvium.

Maitland.-- Municipal water supply. City has one well located in Nodaway River alluvium. The well is 45 feet deep and pumps approximately 150 gpm. Water is chlorinated.

Mound City.-- Municipal water supply. City has two wells located in Missouri River alluvium. The north well is 100 feet deep, the south well is 85 feet deep. Each well pumps 150 gpm. Water is filtered and chlorinated.

Oregon.-- Municipal water supply. City has two wells located in Missouri River alluvium. Wells are 95 feet deep. They are pumped separately and each well is capable of pumping 200 gpm. Water treatment consists of aeration, filtration, chlorination, and Zeolite treatment.

EXPLANATION OF PLATES

The information shown on the Thickness Map (Plate 1) and the Bedrock Contour Map (Plate 2) is accurate only to the degree of presently known data. As more information becomes available, these maps will be modified. The Thickness Map, based on the Bedrock Contour Map, is very generalized.

Plate 1 - Thickness of Unconsolidated Material Map.-- This map, by means of patterns, shows the thickness of the unconsolidated material overlying the bedrock. In general, it can be said that the thicker the unconsolidated material, the greater the possibility of encountering water-bearing material. This map may be used to estimate the amount of

potential water-bearing material available and the approximate depth of a well at a given point. The legend on the map shows the various thickness intervals used and the average estimated water possibilities from various thicknesses. The figures used for the water possibilities are only an estimate, and yields above and below those figures may be encountered.

Figure 2 illustrates the manner in which the thickness map may be used. Point A lies in an area where the maximum thickness of unconsolidated material is approximately 200 feet, and water possibilities are judged to be good. An estimate of the maximum cost of a well or test hole at location A can be made by multiplying the cost per foot of a test hole or completed well by the maximum probable thickness in

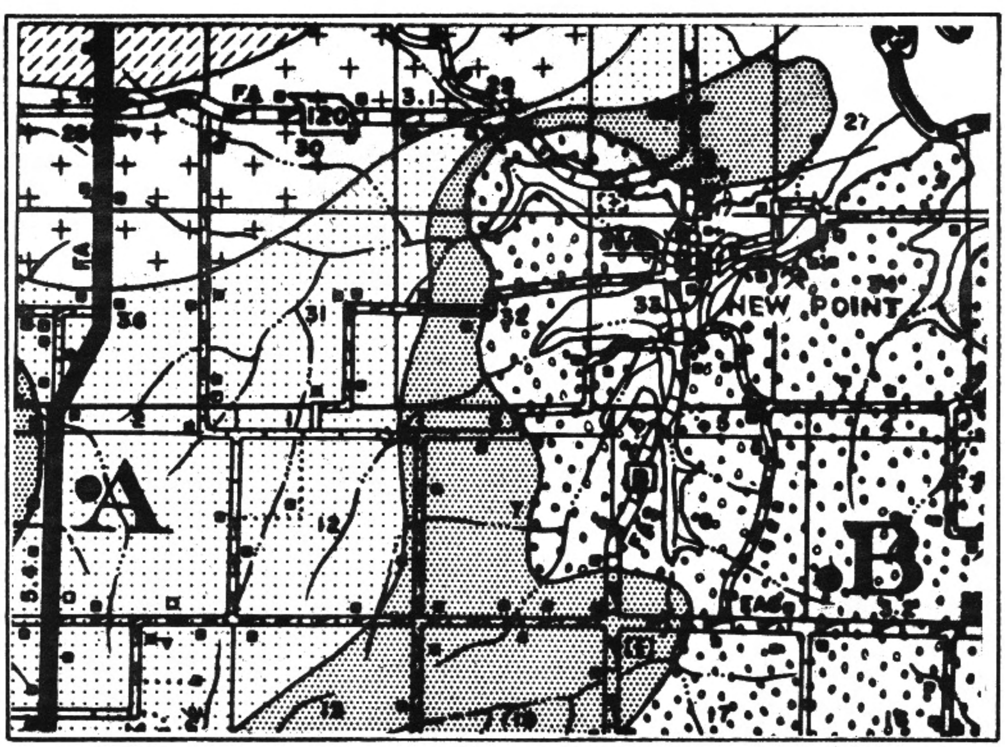


Figure 2. See Plate I for description of patterns.

this case, 200 feet. Since water-bearing material may be encountered at less than 200 feet, this is an estimate of the maximum cost. Point B lies in an area where the maximum thickness of unconsolidated material is approximately 50 feet and the water possibilities are likely to be poor.

Plate 2 - Bedrock Contour Map.-- This map, by means of contour lines, shows the configuration of the bedrock surface based on intrepretation from drill hole data and bedrock exposures. This is the way the land surface would probably appear if all the unconsolidated material were removed. Contour lines are imaginary lines connecting points of equal elevation. The bedrock contour map shows the valley system buried by glacial deposits. It was used in preparation of the map showing the thickness of unconsolidated material.

SUMMARY

Properly constructed wells in the Missouri River alluvium can be expected to produce quantities of 1000 gpm or more. The Nodaway River alluvium will produce sufficient amounts of water for domestic purposes, small municipalities, and possibly irrigation. This water normally needs softening and treatment for removal of iron.

The occurrence of water in glacial deposits is more variable than water from alluvial deposits. Shallow wells, less than 50 feet in depth, commonly experience seasonal variations in water level. In periods of prolonged drought, these wells very often go dry. The deeper wells are more likely to be consistent and will produce larger quantities of water than the shallow wells. The water possibilities in southern

Holt County (the New Point, Oregon, Curzon, and Forbes area) are poor due to the thin deposits of glacial material overlying the bedrock.

The buried river valleys are areas of potentially high-yield wells. However, because there are on record some wells of low-yield within these valleys, it is recommended that all the information available for such an area be obtained before any test is drilled.

Water from the glacial deposits may need treatment for hardness and removal of iron.

The possibility of obtaining usable water from bedrock is very remote. In Holt County, bedrock water is generally too highly mineralized to be fit for human consumption.

For further information write: Missouri Geological Survey and Water Resources, Post Office Box 250, Rolla, Missouri 65401. When writing for information, please send the exact location of your property. To aid in determining your location, see the page at the end of the re-report explaining the government land divisions.

TABLE 3

CHEMICAL ANALYSES OF WATER FROM VARIOUS SOURCES

Water from Missouri River Alluvium

Source: Oregon municipal supply, wells number 1 and 2

Constituents	Minimum	Maximum	Average	Number of Analyses
	Parts Per Million			
Turbidity	10.0	40.0	28.1	5
Color	——	——	none	5
pH	7.0	7.6	7.3	5
Alkalinity ($CaCO_3$)	411.0	471.0	430.0	5
Bicarbonate (HCO_3^-)	501.2	574.0	524.2	5
Silica (SiO_2)	12.0	22.0	18.4	5
Iron (Fe)	3.5	6.0	4.3	5
Aluminum (Al)	0.1-	0.1	0.1-	3
Manganese (Mn)	0.1-	0.1	0.1-	4
Sodium (Na) and Potassium (K) as Na	16.4	78.2	31.5	5
Calcium (Ca)	112.8	207.2	150.4	5
Magnesium (Mg)	48.4	75.8	61.4	5
Sulfate (SO4)	117.9	156.4	140.2	5
Chlorides (Cl)	13.8	242.0	66.4	5
Fluoride (F)	0.1-	0.2	0.1	3
Residue on Evaporation	724.0	1354.0	881.2	5
Loss on Ignition	241.0	619.0	333.6	5
Total Hardness ($CaCO_3$)	541.0	829.0	628.6	5
Carbonate Hardness ($CaCO_3$)	407.0	471.0	427.6	5
Noncarbonate Hardness ($CaCO_3$)	153.0	358.0	201.0	5
Nitrate Nitrogen (N)	0.05	0.34	0.12	5

TABLE 3 (Cont.)

Water from Missouri River Alluvium

Source: Mound City municipal supply, wells number 1 and 2

Constituents	Minimum	Maximum	Average	Number of Analyses
	Parts Per Million			
Turbidity	10.0	40.0	23.3	18
Color	____	____	none	19
pH	6.8	7.1	7.0	13
Alkalinity ($CaCO_3$)	319.0	395.0	351.4	19
Bicarbonate (HCO_3^-)	389.0	480.4	428.3	19
Insoluble	17.6	21.6	19.8	6
Silica (SiO_2)	12.0	24.0	18.6	13
Iron and Aluminum Oxides ($Al_2O_3Fe_2O_3$)	1.6	2.0	1.6	5
Iron (Fe)	0.8	5.0	2.7	19
Aluminum (Al)	0.1-	0.1	0.1-	14
Sodium (Na) and Potassium (K) as Na	16.5	24.1	18.7	19
Calcium (Ca)	97.0	110.0	101.2	19
Magnesium (Mg)	24.5	31.9	29.8	19
Sulfate (SO_4)	11.7	54.3	32.5	19
Chloride (Cl)	6.7	24.4	17.3	19
Residue on Evaporation	438.0	572.0	530.7	19
Loss on Ignition	116.0	249.0	214.2	19
Total Hardness ($CaCO_3$)	348.0	413.0	371.4	19
Carbonate Hardness ($CaCO_3$)	319.0	369.0	348.7	17
Noncarbonate Hardness ($CaCO_3$)	7.0	57.0	27.5	17
Nitrate Nitrogen (N)	0.0	0.92	0.28	19

TABLE 3 (Cont.)

Water from Missouri River Alluvium

Source: Craig municipal supply, 2 analyses

Constituents	A	B
	Parts Per Million	
Turbidity	12.0	25.0
pH	7.2	7.0
Alkalinity ($CaCO_3$)	391.9	394.0
Carbonate (CO_3)	0.0	0.0
Bicarbonate (HCO_3)	477.6	480.5
Silica (SiO_2)	24.0	20.0
Calcium (Ca)	152.0	122.1
Magnesium (Mg)	53.5	53.8
Sodium (Na) and Potassium (K) as Na	74.8	49.2
Iron (Fe)	3.5	7.0
Aluminum (Al)	0.1-	0.1-
Sulfate (SO_4)	16.9	17.3
Chloride (Cl)	249.4	154.0
Total Dissolved Solids	1091.0	817.0
Total Hardness ($CaCO_3$)	600.0	526.0
Carbonate Hardness ($CaCO_3$)	392.0	394.0
Noncarbonate Hardness ($CaCO_3$)	208.0	132.0
Loss on Ignition	528.0	336.0
Nitrate Nitrogen (N)	0.09	0.1

TABLE 3 (Cont.)

Water from Nodaway River Alluvium

Source: Maitland municipal supply

Constituents	Minimum	Maximum	Average	Number of Analyses
	Parts Per Million			
Turbidity	0.1	10.0	1.8	13
Color	—	—	none	14
pH	6.3	6.7	6.4	9
Alkalinity ($CaCO_3$)	64.0	111.0	78.1	14
Bicarbonate (HCO_3)	77.7	135.9	95.3	14
Insoluble	11.6	22.8	19.9	5
Silica (SiO_2)	12.0	30.0	20.2	9
Iron and Aluminum Oxide ($Al_2O_3Fe_2O_3$)	0.8	2.0	1.3	4
Iron (Fe)	0.02	0.7	0.03	14
Aluminum (Al)	0.1-	0.1-	0.1-	10
Sodium (Na) and Potassium (K) as Na	7.4	14.4	11.3	14
Calcium (Ca)	24.4	37.6	29.4	14
Magnesium (Mg)	6.0	13.3	8.8	14
Sulfate (SO_4)	25.7	47.3	32.6	14
Chloride (Cl)	7.2	11.2	9.1	14
Residue on Evaporation	170.0	480.0	261.4	14
Loss on Ignition	71.0	247.0	118.2	14
Total Hardness ($CaCO_3$)	92.0	139.0	110.0	14
Carbonate Hardness ($CaCO_3$)	64.0	111.0	78.0	14
Noncarbonate Hardness ($CaCO_3$)	21.0	57.0	32.0	14
Nitrate Nitrogen (N)	0.97	5.1	2.6	14

TABLE 3 (Cont.)

Water from Glacial Deposits

Source A - William Stone
SE¼ NE¼ sec. 9, T. 62 N., R. 39 W.
Depth of well - 212 feet

B - D. L. Meyer
SE¼ sec. 22, T. 62 N., R. 39 W.
Depth of well - 215 feet

Constituents	A (Parts Per Million)	B (Parts Per Million)
Turbidity	2.0	4.0
pH	7.25	7.15
Alkalinity ($CaCO_3$)	325.0	333.0
Phenolpthalein	0.0	0.0
Methyl Orange	325.0	333.0
Carbonate (CO_3)	0.0	0.0
Bicarbonate (HCO_3)	396.5	406.3
Silica (SiO_2)	20.0	13.0
Oxides (Al_2O_3, Fe_2O_3, TiO_2, etc.)	1.0	0.6
Calcium (Ca)	66.0	128.1
Magnesium (Mg)	24.0	34.6
Sodium (Na) and Potassium (K) as Na	92.1	47.2
Total Manganese (Mn)	0.0	0.0
Total Iron (Fe)	0.23	1.08
Dissolved Iron	0.03	0.03
Precipitated Iron	0.20	1.05
Sulfate (SO_4)	18.9	31.0
Chloride (Cl)	73.5	65.5
Nitrate (NO_3)	2.8	103.6*
Fluoride (F)	0.3	0.1
Total Suspended Matter	4.0	2.0
Total Dissolved Solids	507.0	774.0
Total Hardness ($CaCO_3$)	263.6	462.3
Carbonate Hardness ($CaCO_3$)	263.6	333.0
Noncarbonate Hardness ($CaCO_3$)	0.0	129.3

*Nitrate high in Analysis B due to surface contamination.

TABLE 3 (Cont.)

Water from Bedrock

Source: A and B - Owner: Mutual Benefit Life Insurance Company J. Tyson farm

Location: NW¼ NW¼ SW¼ sec. 32, T. 60 N., R. 37 W.

Depth of Sample: A - 500 feet. Bailed from bottom of hole.
B - From top of column. 170 feet static water level (SWL).
Well bottomed in Pennsylvanian (Douglas Group). The discrepancies between A and B indicate that much of sample B is water from glacial material above bedrock.

C - Owner: E. Kneale
Location: NE¼ NW¼ NE¼ sec. 20, T. 60 N., R. 37 W.
Depth of Sample: 365-398 Pennsylvanian sandstone. (Lawrence Formation)

D-H - Owner: Nathan and Brinn - Decker # 1
Location: CNW¼ NW¼ sec. 1, T. 61 N., R. 38 W.
Depth of Sample: D - 1445-1594 feet. Pennsylvanian sandstone (Lower Cherokee).
E - 1882-1892 feet. Mississippian (Ste. Genevieve).
F - 2029-2033 feet. Mississippian (Warsaw?).
G - 2255-2256 feet. Mississippian (Kinderhook?).
H - 2308 feet. Devonian.

Constituents	A	B	C	D	E	F	G	H
	Parts Per Million							
Alkalinity ($CaCO_3$)	317.6	293.0	385.5	515.4	805.8	570.7	477.4	270.9
Carbonate (CO_3)	0.0	4.2	0.0	27.7	12.4	0.0	0.0	0.0
Bicarbonate (HCO_3)	387.3	353.0	470.1	600.4	970.1	696.0	558.2	330.4
Silica (SiO_2)	4.4	12.8	7.2	4.8	5.6	18.0	8.0	12.8
Oxides (R_2O_3)	2.0	0.8	1.6	0.8	1.2	3.6	1.2	1.6
Calcium (Ca)	91.6	29.1	31.2	9.4	13.1	28.3	21.1	101.7
Magnesium (Mg)	53.7	17.6	18.8	5.5	5.4	9.3	7.8	50.6
Sodium (Na) and Potassium (K) as Na	3459.1	119.6	1787.6	1095.2	1228.2	1319.5	1232.1	827.7
Sulfate (SO_4)	669.3	41.8	1313.7	586.6	571.8	645.2	581.0	1246.6
Chloride (Cl)	4730.8	36.0	1642.1	928.5	941.9	1254.4	1160.6	531.2
Total Dissolved Solids	9535.0	480.0	5118.0	3038.0	3312.0	3687.0	3353.0	3082.0
Total Hardness ($CaCO_3$)	449.2	143.7	155.1	46.1	54.9	108.9	84.7	462.5
Carbonate Hardness ($CaCO_3$)	317.6	143.7	155.1	46.1	54.9	108.9	84.7	270.9

BIBLIOGRAPHY

Bennison, E. W., 1947, Ground water, its development, uses, and conservation: Edward E. Johnson, Inc., St. Paul, 509 pp.

Flint, R. F., 1957, Glacial and Pleistocene geology: John Wiley & Sons, Inc., New York, 553 pp., 5 pls., 133 figs., 51 tables.

Frye, J. C., and Leonard, A. B., 1952, Pleistocene geology of Kansas: Kansas Geol. Survey, Bull. 99, 230 pp., 19 pls., 17 figs.

Fuller, Dale, McMillen, J. R., Pick, Harry, Russell, W. B., and Wells, Jack, 1957, Water possibilities from the glacial drift of Andrew County: Missouri Geol. Survey and Water Resources, Water Resources Rept. No. 15, 10 pp., 3 pls.

Greene, F. C., and Trowbridge, R. M., 1935, Pre-glacial drainage pattern of northwest Missouri: Missouri Bur. Geology and Mines, 58th Bienn. Rept. State Geologist, 1933-1934, app. 7, 7 pp.

Heim, G. E., Martin, J. A., and Howe, W. B., 1959, Preliminary report on the groundwater resources of Nodaway County, Missouri: Missouri Geol. Survey and Water Resources, Water Resources Rept. No. 16, 24 pp., 2 pls., 1 fig., 3 tables.

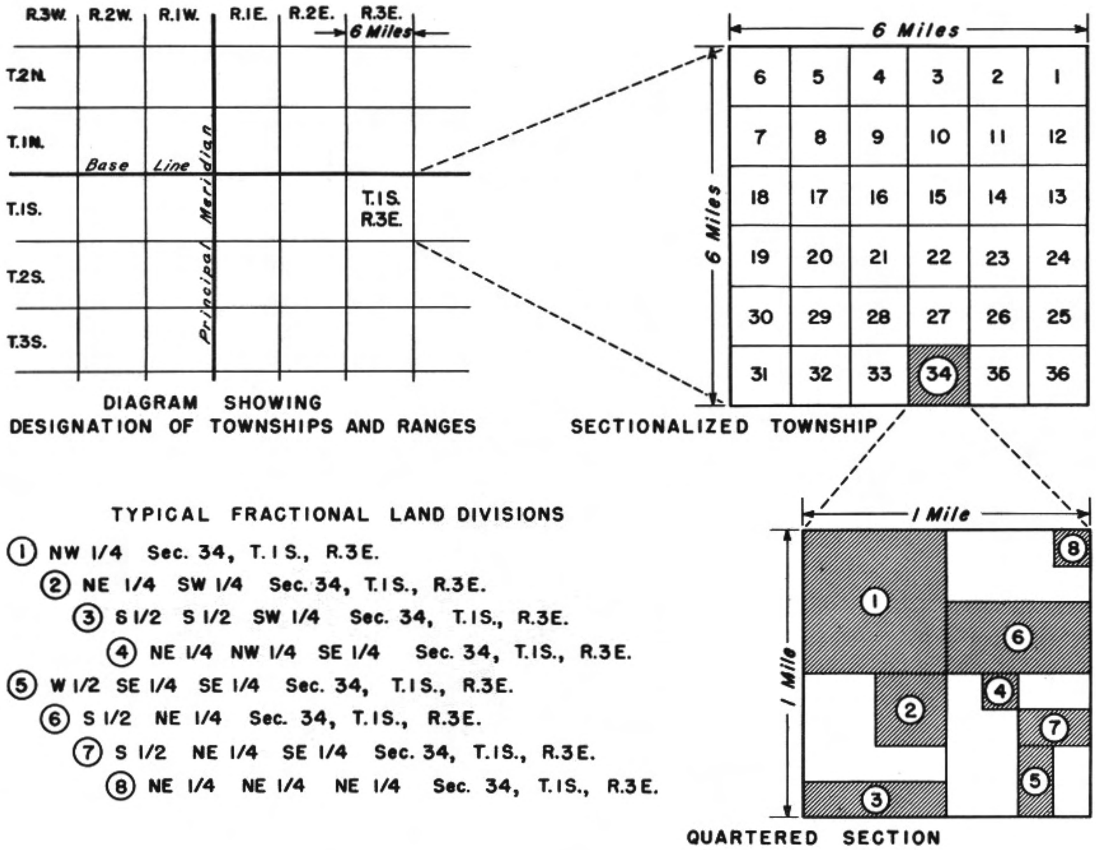
Hinds, Henry, and Greene, F. C., 1915, The stratigraphy of the Pennsylvanian series in Missouri: Missouri Bur. Geology and Mines, 2d ser., vol. 13, 407 pp.

Kay, G. F., and Apfel, E. T., 1928, Pre-Illinoian Pleistocene geology of Iowa: Iowa Geol. Survey Ann. Rept., 1928, vol. 34, pp. 1-304.

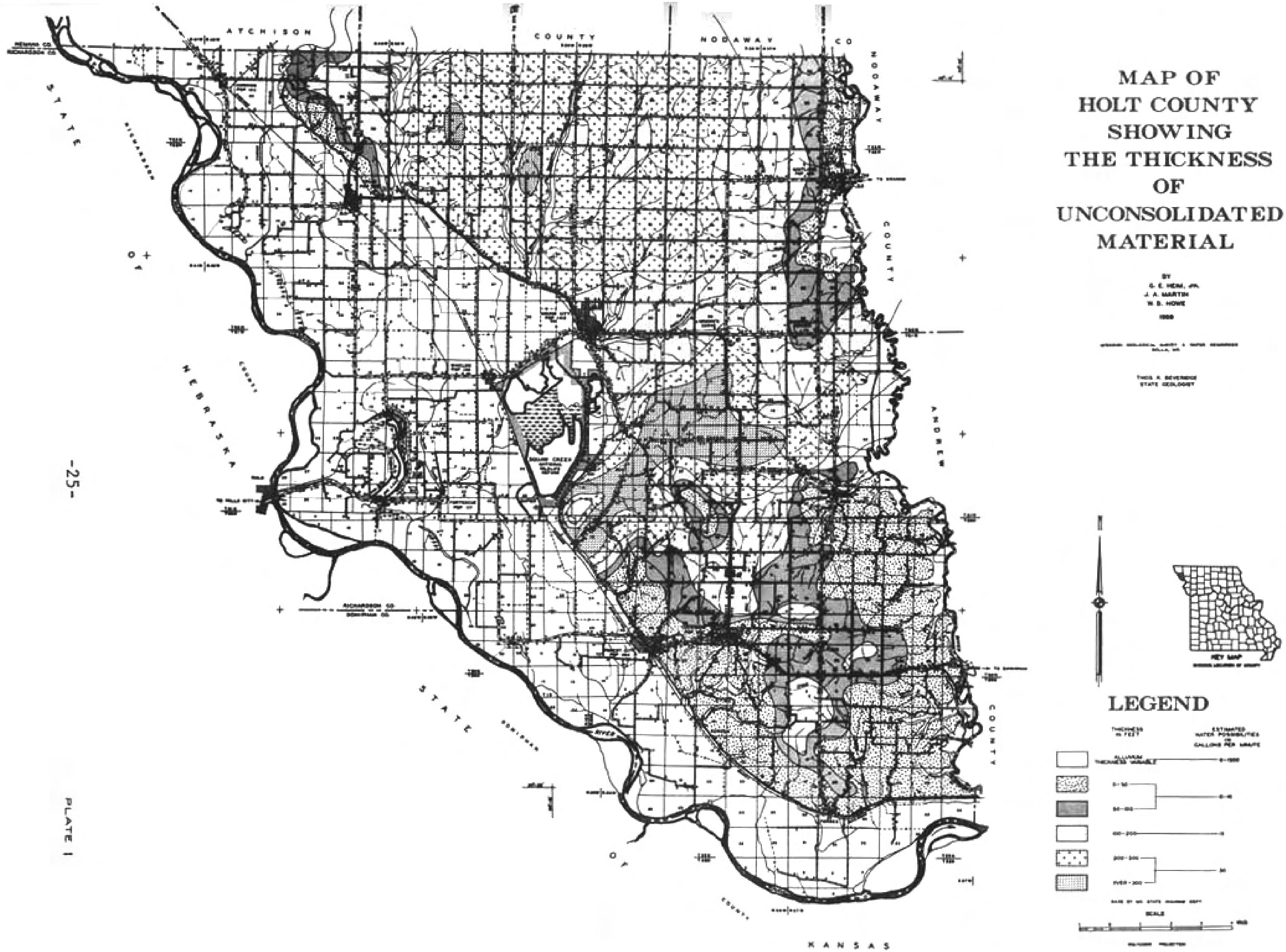
McQueen, H. S., and Greene, F. C., 1938, The geology of northwestern Missouri: Missouri Geol. Survey and Water Resources, 2d ser., vol. 25, 217 pp., 7 pls., 11 figs.

Planalp, R. N., 1955, Stratigraphy of the Oregon Quadrangle, Missouri: Unpublished Master's thesis, Univ. of Missouri, Columbia, Missouri.

Schweitzer, Paul, 1892, A report on the mineral waters of Missouri: Missouri Geol. Survey and Water Resources, vol. 3, 356 pp.



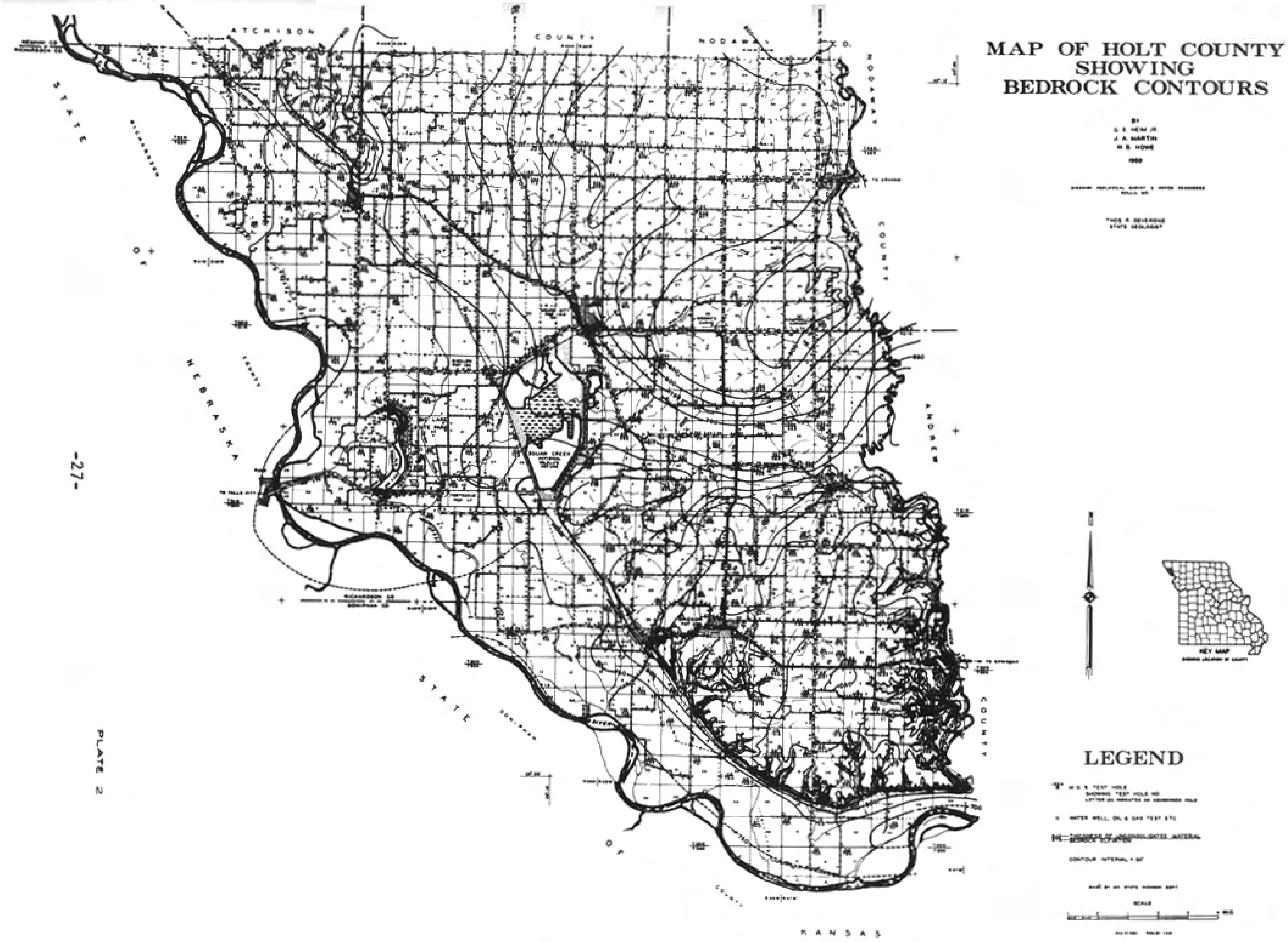
Idealized government land divisions: This diagram illustrates the relationship of fractional land divisions in quartered sections to townships and ranges. The numbered location descriptions to the left of the quartered section corresponds with the numbered and shaded areas in the section which in turn corresponds with the shaded area in the township above it.



MAP OF
HOLT COUNTY
SHOWING
THE THICKNESS
OF
UNCONSOLIDATED
MATERIAL
BY
G. E. HEIM, JR.
J. A. MARTIN
W. B. HOWE
THOS. R. BEVERIDGE
STATE GEOLOGIST
ATCHISON
COUNTY
NODAWAY
CO
NODAWAY
COUNTY
ANDREW
COUNTY
STATE
OF
NEBRASKA
STATE
OF
KANSAS
LEGEND
THICKNESS IN FEET
ESTIMATED WATER POSSIBILITIES IN GALLONS PER MINUTE
ALLUVIUM THICKNESS VARIABLE
0-50
50-100
100-200
200-300
OVER-300
SCALE

-25-

PLATE I



MAP OF HOLT COUNTY
SHOWING
BEDROCK CONTOURS
BY
G. E. HEIM JR.
J. A. MARTIN
W. B. HOWE
THOS R. BEVERIDGE
STATE GEOLOGIST
LEGEND
KEY MAP
SCALE
ATCHISON COUNTY
NODAWAY CO.
NODAWAY COUNTY
ANDREW COUNTY
STATE OF NEBRASKA
STATE OF KANSAS
RICHARDSON CO.
DONIPHAN CO.
SQUAW CREEK

PLATE 2